DOCUMENT RESUME

ED 406 150 SE 059 810

AUTHOR Segal, Gilda
TITLE A Sociocultural Model of Learning and Teaching in Early Childhood Science Education.
PUB DATE Mar 97
NOTE 43p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (70th, Oak Brook, IL, March, 1997).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Active Learning; *Cognitive Processes; Concept Formation; Cooperation; Critical Thinking; Cultural Background; *Discussion (Teaching Technique); Experiential Learning; Foreign Countries; Group Activities; Inquiry; Learning Theories; *Modeling (Psychology); Primary Education; *Science Instruction; *Sociocultural Patterns; Student Journals; Student Reaction; Teaching Methods
IDENTIFIERS Australia (Sydney)

ABSTRACT

The purposes of this study were to: (1) investigate the process of development of young children's ideas when (and if) they appropriate science from the conceptual area (i.e., light) during whole-class and small-group interactions; and (2) advance understanding of relationships between a collaboratively designed learning and teaching model and children's developing scientific knowledge. This paper discusses children's learning in a Year 1/2 class. Children cooperated with their teacher's skillful modeling of how to conduct fruitful discussion. The high engagement of children in class discussions was revealed by their ever-lengthening and increasingly fluent contributions. Children expressed complex ideas while their classmates listened intently and interacted directly with the contributor, unmodulated by their teacher. The informal inquiry sessions where children could investigate their own questions or those generated in class discussion stimulated further thinking about the learning-model context and provided material for reflection on learning. Mediational means for the development of children's thinking can be attributed to child, teacher, and parental characteristics grounded in their middle-class culture and values, in the design of the learning and teaching model, and in the use children made of their personal learning journals. Contains 51 references. (Author/PVD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL
HAS BEEN GRANTED BY

G. Segal

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
This document has been reproduced as
received from the person or organization
originating it.
☐ Minor changes have been made to
improve reproduction quality.
• Points of view or opinions stated in this
document do not necessarily represent
official OERI position or policy.

ED 406 150

A SOCIOCULTURAL MODEL OF LEARNING AND TEACHING IN EARLY CHILDHOOD SCIENCE EDUCATION

Gilda Segal
University of Technology, Sydney

Paper presented at Annual Meeting of
National Association for Research in Science Teaching (NARST)
Chicago, March, 1997

Email:
G.Segal@uts.edu.au

Address:
School of Teacher Education,
University of Technology, Sydney,
Eton Road, LINDFIELD, NSW
AUSTRALIA 2070

BEST COPY AVAILABLE

SE057810

A SOCIOCULTURAL MODEL OF LEARNING AND TEACHING IN EARLY CHILDHOOD SCIENCE EDUCATION

by

GILDA SEGAL

University of Technology Sydney

ABSTRACT

The purposes of this study were first, to investigate the process of development of young children's ideas when (and if) they appropriate science from the conceptual area, *light*, during whole class and small group interactions; and second, to advance understanding of relationships between a collaboratively designed learning and teaching model and children's developing scientific knowledge. This paper tells the story of children's learning in a Year 1/2 class. Children cooperated with their teacher's skilful modelling of how to conduct fruitful discussion. The high engagement of children in class discussions was revealed by their ever-lengthening and increasingly fluent contributions. Children expressed complex ideas; their classmates listened intently and interacted directly with the contributor, unmodulated by their teacher. The informal inquiry sessions, where children could investigate their own questions, or those generated in class discussion, stimulated further deep thinking about the learning model context and provided material for reflection on learning. Mediational means for development of children's thinking can be attributed to child, teacher and parental characteristics grounded in their middle class culture and values, in the design of the learning and teaching model and in the use children made of their personal learning journals.

BACKGROUND

Many science-alienated students have experienced didactic, teacher-dominated lessons in secondary science, where science content is transmitted in a monologic fashion, exclusive of learners' interests, background experiences or preferences (Seddon, 1991). This style of teaching is not in accord with theories of learning such as sociocultural theory (Rogoff, 1990) and dynamic systems theory (Thelen & Smith, 1994; Thelen & Ulrich, 1991) which are grounded in empirical studies of babies, young children and adults engaging in successful learning in a variety of everyday contexts. By understanding processes that lead to successful and enjoyable learning under out-of-school conditions and the theoretical perspectives that illuminate those processes, we may be able to design models of learning and teaching that encourage children to engage successfully in science education within school.

Sociocultural Perspectives On Learning

Sociocultural (or sociohistorical) theory, grounded in Vygotsky's theory of learning (Vygotsky, 1962; Vygotsky, 1978), views learning as a set of dialectical relationships between an individual's mental processes and their cultural, historical and institutional setting (Wertsch, 1991). Sociohistorical theory according to Rogoff (1990) offers "a unique seamlessness of individual, social and historical (or cultural) processes" (p. 13); the theory, according to Cole (1985) treats cognitive development as a process of acquiring culture. In Bruner's (1962) view, Vygotsky's thinking is "very much in accord with the more modern work of physical anthropologists who have speculated on the use of hand 'pebble tools' in shaping the evolution of Australopithecus and other hominids" (p. vii). A sociocultural perspective is also consistent with dynamic systems theory developed by Thelen and Smith (1994), that explains the social embeddedness of thought by "building a case for mental life as emergent from the activities of everyday life" (p. 329).

The connection that Bruner (1962) makes between hand, action and brain, foreshadows the way that Wertsch (1991) draws on the work of Bateson (1972) and Geertz (1973) in his theoretical extension of Vygotsky's theory of mind. Wertsch theorises mind as being more than the contents of an individual's brain. He views memory and reasoning as being socially distributed: Firstly through examples of mind distributed among mental actions of an individual and that individual's mediational means (such as computers, books, language and other tools); and secondly through examples of mind distributed among group members (through imagining a group's engagement in joint planning; the emerging plan cannot be attributed to any one individual's mental functioning alone).

Appropriation and Analysis of Learning

Adopting sociocultural analytical perspectives to understand learning means there is no need to separate psychological processes of learners from their sociocultural context, as analysis can focus on a whole picture of learners appropriating science. Rogoff (1990), like Newman (1990), prefers to speak of appropriation, instead of internalisation as a process within Vygotskian theory. Rather than assuming that individuals, separate from each other, need to transfer from outside across some barrier to inside to form products of joint collaboration, Rogoff suggests an alternative analytical frame:

> Benefiting from shared thinking does not involve *taking* something from an external model. Instead, in the process of participation in social activity, the individual already functions with the shared understanding (p. 195) ...
> The individual's later use of this shared understanding ... is an appropriation of the shared activity by each individual and reflects the individual's understanding of and involvement in the activity (p. 195).

Newman (1990) expresses the same sentiments when he says: "Some of the process which constructs new knowledge can be occurring in the *interaction* rather than exclusively in the head of the student" (p. 87, italics in original). These definitions mean that to comprehend whether learners have appropriated science, mediational means of assisting learning need to be identified and interactive processes and relationships during learning need to be analysed. This analysis challenges psychological understandings that are focussed solely on an individual's mental processes and at the same time challenges other psychological assumptions centred on individuals, for example that agency can only be a property of an individual (Wertsch, Tulviste & Hagstrom, 1993).

Biological Perspectives on Learning

Within a human brain, there are billions of possible connections between nerve cells; the brain must have some way of selecting those patterns that produce useful behaviour (Millson & Sington, 1994). This process is thought to originate through the influence of a few inherited neurons, called value systems, situated in the brain stem and evolved to recognise structures and events in the environment that are of adaptive value to the organism (Millson & Sington, 1994). Events that are of adaptive value could be simply that moving objects are more interesting than still objects (Spelke, 1991; Thelen & Smith, 1994), or they could be activities such as eating and sleeping (Millson & Sington, 1994). From these theoretical perspectives, learning is inferred to be intimately related to the value that the learner places on what is to be learned (Edelman, 1993; Millson & Sington, 1994).

Sometimes what is of value for learners can be inferred through observations of endpoints of learning in particular contexts. For example, learning through selection of favoured paths of brain neurons (Edelman, 1993) that act in concert with other body systems leads normal babies to learn to walk, talk and reach (Lockman & Thelen, 1993; Thelen & Ulrich, 1991; Thelen et al., 1993). Although it may appear that this kind of learning is gene-instructed and therefore species prescriptive, observations of wolf-children provide convincing arguments to the contrary. For wolf-children, who sometimes walk on all fours, who howl like those animals and who seem impervious to cold (McCrone, 1993), it can be inferred that denied human contact, different learning end-points have emerged that have survival value for them.

From this summarised neuroscientific view of learning, students choose to learn science if they feel that what is learned and how it is learned is of value to them. Hence, those relationships that learners choose to make with and within social and cultural contexts can be deemed to have more value for learners than relationships that learners do not make.

Value, prior knowledge and interest

Value is also associated with constructs such as *interest, relevance, familiarity, prior knowledge,* and *motivation* on a macro level of the clarification of influences on learning. Science education researchers of the early 1980s ignored influences of affect on learning in their search for ways of changing students' intuitive ideas into scientifically accepted views and did not build these constructs into their early purely cognitive models of conceptual change (e.g. Posner & Gertzog, 1982; Strike & Posner, 1985). However, more sophisticated models that take account of affect in science education have been developed, for example a model of generative learning (Wittrock, 1994) and a model of conceptual change (Pintrich, Marx & Boyle, 1993), so this situation is changing.

Tobias (1994) suggests from his review of findings linking interest, value, prior knowledge, domain knowledge and topic or subject-matter knowledge that "interest may have an energizing effect on learning and lead students to use deep comprehension processes" (p. 45). Alexander et al. (1994) report that subject-matter knowledge, particularly domain knowledge, predicts both recall and interest in popular press reading in the physics domain. These findings, taken together, highlight the interactive nature of the constructs of interest, value, prior knowledge, domain knowledge and subject-matter knowledge and support the design of models of learning that do not try artificially to separate the constructs.

Recapitulating, to join these macro and micro understandings of value, interest and relevance together, in Tobias' (1994) words:

> Interest contributes to learning in the following ways: invokes deeper types of comprehension processes, leads to greater use of imagery, and may stimulate a more emotional, more personal, and *more extensive network of relevant associations* than is invoked by prior knowledge. (p. 50, italics added)

Hence the meaning of *value* of learning science for a student is defined here on neuroscientific and macro levels. On a neuroscientific level many associative neuronal networks are selected under the influence of value systems in the brain when a student forms relationships with science during learning urges. On a macro level, evidence of formation of many neuronal networks can be sought in the student's involvement and engagement in many facets of science discipline experiences during and outside of class times. An observer might therefore infer that science learning has been of personal value to students when students spontaneously report their interest and joy in learning, and when there is evidence in students' demeanour of high involvement during learning. Students' high engagement in their learning may lead to deep learning (Entwistle, 1988).

In the following section, I explain how these theoretical and empirical insights provided the foundation for principles of design of the sociocultural learning and teaching model developed for this research.

DEVELOPMENT OF A SOCIOCULTURAL MODEL OF LEARNING AND TEACHING

A central aspect underpinning the learning and teaching model design for this study is that children are to be encouraged to develop their willingness and capacities to participate in what I have termed *transformational interactions* to assist and deepen their understanding of subject(s) of interest. Before delineating my design principles for the model, I first explain my conceptualisation of transformational interactions, secondly discuss conditions that have been shown to encourage children to participate in such interactions at home, and thirdly, I extrapolate from those successful home conditions to suggest necessary conditions that will favour children's participation in such interactions at school.

Transformational Interactions

I have conceptualised a transformational interaction to be one that shares some important features of deep conversational interactions that people hold to clarify their understanding about an event that they hold to be important. Transformational interactions develop from the participants' life experiences, and/or actions and activities within familiar contexts. They may be relatively brief or extended, but share the following features:

1. They are about events that eventually (if not at first) become significant to participants.
2. Meaning of events discussed may be emergent, not obvious at first. If one participant does have greater knowledge of events than others, didacticism is usually absent during processes of negotiating understanding.
3. Participants are tolerant of divergent views, but are driven by a need to reach shared understanding.
4. They are not time-dependent. They may be non-linear and sometimes even appear to be chaotic.
5. Interactions are of value to each participant.

So through transformational interactions, participants appropriate the shared meaning of the event under discussion. If that event is salient, then it may be the topic of transformational interactions in the future, where participants might hold conversations to develop further meaning; in so doing, they may uncover layers of deeper complexity about the event. The value of participating in transformational interactions, is that (according to sociocultural theorising), shared discourse becomes thought, recursively acting as resources for further communicative speech (Berk, 1994; Bershon, 1992; Vygotsky, 1962; Vygotsky, 1978).

I am also making the assumption grounded in the post-structuralist theory of (Foucault, 1977) that transformational interactions, as discourse, develop the subjectivities of participants. The post-structuralist term *subjectivities* describes the processes of becoming a person. Unlike the modernist term *identity*, that is conceived as semi-fixed, "subjectivities are achieved through

relations with others (both real and imagined) which are themselves made possible through discourse" (Davies, 1993, p. 9). Foucault analyses discourses to mean "practices that systematically form the objects of which they speak ... Discourses are not about objects; they constitute them and in the practice of doing so, conceal their own intervention" (Foucault, 1977, p 49, cited in Kenway, Willis, Blackmore & Rennie, 1994, p. 189).

During transformational interactions that develop children's ideas, everyday phenomena and that simultaneously develop their subjectivities, there are roles for parents/carers at home. These parental/carer roles at home suggest roles for teachers and/or more experienced peers at school.

Developing children's ideas during transformational interactions at home

Parents are successful in assisting their children's learning; practically all normal children effortlessly learn complexities of talking and acting under home conditions. As Bruner (1977) elucidates, "All forms of assisted learning depend massively upon a dialogue carefully stabilised by the adult partner" (p. xiv). In their daily activities at home, children learn generatively in and through intense, rich, complex, intellectually-driven conversations about their activities with sensitive mothers as illustrated by the research of Tizard and Hughes (1984). Tizard and Hughes found that the quality of interactions of those same children with their preschool teachers was markedly poorer; children responded with one word answers to closed questioning of teachers instead of using the complex language characteristic of home conversations. This finding vividly contrasts the central role that context and conversations play in learning at home and at school. As pointed out by Wood (1988) the child at home drives the communication process, perhaps initially through innate structures (Trevarthen, 1992), but at school, the process is teacher-driven.

Wilensky (1991) suggests that engagement by learners in a constructionist paradigm for learning (Harel & Papert, 1990) will help children learn for "when we construct objects in the world, we come into engaged relationship with them and the knowledge needed for their construction. It is especially likely then, that we will make this knowledge concrete" (Wilensky, 1991, p. 202). For many children, the combination of a constructionist paradigm and transformational interactions is available at home, but not at school.

Developing children's ideas during transformational interactions at school

For successful reproduction of home-type interactional contexts at school, where those interactions are to be held to develop children's ideas about scientific phenomena, I postulate that contexts chosen for such interactions should:

1. Be intellectually accessible to the age group for which they are chosen.
2. Offer stimulating and enjoyable possibilities for exploration with materials that are familiar to the potential conversants.

3. Lend themselves to developing young children's thinking towards scientific understanding in an area of the discipline that is significant.
4. Include learning guides to assist those who are inexperienced to participate in conversations and complete tasks they could not otherwise complete alone. This incorporates Vygotskian assumptions of modelling by teachers and more experienced peers. Therein, children learn how to participate in deep conversations about ready-made science and science-in-the-making (Latour, 1987); participants develop common knowledge (after Edwards & Mercer, 1987) that becomes the resource of reflection and further thinking. In other words, children need to be immersed in discourses of science that are new to them (Gee, 1990, 1994); they can then gradually assume more responsibility for their learning during this constitution of their subjectivities.

Roles For Teachers In Transformational interactions

As already indicated, provision of assistance for learners to accomplish with experienced educators what they cannot yet accomplish alone is an assumption of learning models based upon Vygotskian theory. While this analysis indicates a role for the teacher, which Bruner (1977) calls scaffolding, Cazden (1988) warns that this could easily fall back into behaviourist conditioning. Citing Engeström (1986), she notes that "scaffolds as an instructional model cannot account for the mental leap to a new idea" (p. 108). Her concern is that models of learning and teaching based only on modelling and instruction leave no place for creativity. Hence in my principles of design, I have included specifications of contexts that are not only familiar to young children, but that lend themselves to autonomous inquiry. As is evident from its grounding in sociocultural theory, having a teacher who not only understands the theoretical underpinnings of her role, but who is well informed about the scientific concepts within the chosen context of significance, is crucial to the success of the model.

Towards Principles of Design

Design principles for my sociocultural learning and teaching model may now be stated. The model is to be designed to:

1. Be experiential, allowing learners to act and make inquiries in contexts that are assumed to be familiar (and hence relevant and of interest) to them.
2. Be dialogic, developing learners' ideas during their participation in transformational interactions about a significant area of scientific discipline knowledge embedded in familiar learning model context (*light*).
3. Provide learners with the assistance of teachers who are knowledgeable about what is to be learned, about sociocultural theories of learning and about their role according to this theory.
4. Encourage learners to be active and creative, not passive.

5. Pay particular regard to readiness of learners to appropriate science.
6. Gradually cede control of learning to students.
7. Allow students to reach dignified end-points that may credibly differ for individuals, rather than end-points inevitably marked by failure for many. The model is thus planned to enhance self-esteem and is to take particular care not to damage it.
8. Generate multiple pathways for students to develop relationships with and within familiar contexts to concretise their learning, (Wilensky, 1991) as they learn through repertoire-refinement (Millson & Sington, 1994).
9. Be located in a few areas of significant scientific thought, rather than skimming through many areas in a short time.

By broadening aims, epistemologies and procedures, my intention in this research was to collaborate with practising primary teachers to design a learning and teaching model in accordance with these design parameters to help young children appropriate science during early science learning experiences at school.

RESEARCH DESIGN

Principal Research Question

Stemming from my intentions, the principal research question addressed in this study was:

> Do young children (aged 6 - 8 years) choose to appropriate science from a familiar context of scientific significance (*light*) when they are immersed in a learning and teaching model that meets the design parameters articulated above? (And if so, how?)

Research Paradigm

A research methodology that assists understanding of an individual's appropriation of science will need to consider context and mediational means as inseparable from individual action. A central part of the inquiry will therefore involve identifying and describing dimensions of a network of possible relationships between learner(s), context and science-to -be-learned, because, as I have indicated, relationships forming between learners and a science concept signify aspects of appropriation of that concept. According to Smith (1987), such requirements can be satisfied by a qualitative research methodology. My approaches to qualitative inquiry are a blend of ethnographic (Spindler, 1988), interpretive (Erickson, 1986), naturalistic (Lincoln & Guba, 1985) and artistic (Smith, 1987) inquiry procedures.

Sociocultural Context

The research took place in an elementary school (with which my University was linked in a number of programs) in a middle class area of a large city. Three practising primary teachers collaborated with me to write a Unit on Light during their participation in two of the programs (a *Whole School Professional Development Program in Science Education* and an *Associate Teacher Program*). The teachers then taught the Unit while I was present in their classes as a participant observer. In this paper, I discuss only the research undertaken in one classroom, that of Mrs C. who taught a Year 1/2 composite class. Some findings from the Year 3/4 class have been discussed in an earlier paper (Segal & Cosgrove, 1995).

Sociocultural background of children

Most children in Class 1/2C ($N_1 = 18$; $N_2 = 12$) were of European descent and were all English speakers. Children naturally differed in temperament and confidence. Many children were assured, well-spoken and fluent, overtly interested in the lived-in world and in the world of imagination through reading. A few still became upset, when a parent left the classroom after assisting with learning activities. A few children rarely spoke in class discussion. One child rarely spoke to anyone; other children sometimes told me what she thought, or what her actions meant. (Pseudonyms for children's names are used throughout this paper.)

I visited the classrooms regularly before the Unit began to become familiar with the children and their context. The children readily told me about their interests inside and outside of school. Interests included playing (favoured activities were gendered), reading, writing stories and seeing films; most enjoyed reading fiction, not factual text. Some children (mostly boys) had done science experiments at home and demonstrated them for the class earlier in the year. A few children had science kits and science toys. Mid-unit and at the end of the year, I interviewed all children in small groups to develop my understanding of their experiences, from their perspectives, in the Light Unit.

A brief picture of Mrs C.

Mrs. C. was an experienced teacher - at the time of the study, she was one of the school executive staff in the Relieving Assistant Principal position. I asked Mrs. C. towards the end of the year, if she would write a little about herself for my research, an account of how she became involved in the research and of our work together. As further confirmation of the picture of traditional secondary science education in New South Wales described in the introduction to this paper, she wrote in part:

> Last year our Principal, Mrs. A. asked if any teacher would be interested in working with lecturers from the University of Technology, Sydney - Science Education. My immediate response was 'Great' because my knowledge, skill and competencies were

> not strong in this area...As far as experiments and actual physical science, my own experience was very limited and also due to the learning style endured in my high school days, I never really 'got to do anything' for myself and quite often didn't see or witness any testing or discovering, but rather wrote copious notes from the blackboard! (Mrs. C., written statement, September, 1993)

During our first planning session in early May, 1993, after explaining her experiences of 'chalk and talk', Mrs. C. articulated her view of a purpose of elementary science education, differentiating it from secondary science education as she remembered it:

> If that's the overall thing at the end - the exams and you're basically preparing students for this exam, well we're not preparing students for anything like that. We're preparing them for their life, enjoyment and just for their general knowledge *(inaudible)* development. (Mrs. C., first planning session)

Later in the discussion, Mrs. C. restated how she viewed our proposed learning and teaching style:

> We are actually allowing the children to do the discovering, rather than standing and just telling them. I was just saying that by actually telling children, right or wrong, or telling them how it should be done, I think we're actually limiting the experience that they come in with and the actual knowledge they might have. (Mrs. C. first planning session)

Mrs. C. here articulated an overt challenge to a didacticism associated with the secondary science teaching she had experienced. Further, she expressed an insight into the biological theory of learning that underpins the models of learning and teaching introduced by my University colleague in the Whole School Professional Development Program. That is, Mrs. C. had appropriated the understanding based upon her experience and upon the Professional Development Program, that children learn by making selections based on the value those selections have for them, and that their learning can be inhibited by excessive instruction, if instruction inhibits selection.

Classroom culture

Following Delamont's (1992) advice to note what was strange in the early weeks of my research, I observed that the classroom culture seemed characterised by two features: the mutual respect that Mrs. C. and the children held for each other and the responsibility for learning and other tasks that children assumed.

The mutual respect that I observed between Mrs. C. and the young children in her class was simultaneously strong and sensitive. Mrs. C. modelled by her actions and words how to respect the rights of others, whether that other was an adult or a child. For example, she did not interrupt when children were speaking; she was courteous to adults who entered the room from time to time while

she was teaching, always excusing herself to the children before speaking to the adult. She thanked children for initiatives taken, for help, and for offers of help; she assisted children when they were experiencing difficulties in learning or in social relationships by giving advice to children and parents about problems. Children showed their respect for Mrs. C. by cheerfully engaging in the learning activities she arranged for them; by their silent attention when she was speaking to them; and by offering on many occasions to assist with classroom tasks.

Children were expected to take responsibility for their learning in this class and they did so. On many occasions, Mrs. C. trusted them to decide when they had finished a task; when they wanted a change of task; whether they wanted to work with a partner or alone; how they wanted to present their work; when they wished to work on the classroom computer and in cleaning up the classroom after their use of materials such as egg cartons, cardboard cereal boxes, plastic trays. I attribute these early signs of developing personal and social responsibility in children to Mrs. C.'s valuing them herself and consistently modelling her values through her actions and words during her interactions with others.

Whole School Professional Development Program in Science Education

During the time period of this research, colleagues from my University and I provided a year-long whole school inservice program to introduce teachers to a view of learning which encouraged children to generate and seek answers to their own questions about events that interested them (after Biddulph & Osborne, 1984).

Associate Teacher Program

The other program of relevance to this research, the *Associate Teacher Program*, provided time for practising teachers (called *Colleague Teachers* in the program) to be released from their classes while newly qualified teachers, (called *Associate Teachers)* undertaking further study at my University, taught the classes of the Colleague Teachers. Part of the teacher release time allowed for professional development with a University teacher educator. During my professional development sessions with the three teachers, (22 hours) at the school, they clarified their understanding of some basic properties of light (propagation, formation of shadows and reflection), discussed ideas children may hold about light as revealed by researchers such as Andersson & Kärrqvist, 1983; Feher & Rice, 1988; Piaget, 1970) and wrote the Unit with me. We designed the Unit to have flexible entry points and pathways to be followed according to children's and/or teachers' wishes. During this time, we also designed a learning and teaching model, grounded in the principles of design discussed above and in the teachers' preferred pedagogy.

Collaboration in Model Design

As experienced practising teachers, the teachers who collaborated with me in this research already had preferred pedagogical techniques that could blend with the learning and teaching models that were being presented in the Teacher Development Programs and that could be grounded in my principles of design. We therefore decided that we would design a number of models based upon these principles but that also included specific strategies for early childhood learning and the teachers' preferred modes of teaching. This decision was also grounded in our creative urges. The model that is the subject of this paper, *The On-Going Thinking Model* strongly reflected one teacher's (Mrs C.) preferred modes of interactions with children and she made a substantial contribution to its design.

The On-Going Thinking Model

We designed the On-Going-Thinking Model for teachers to use flexibly with primary children of all ages at the school. Here I concentrate on its purposes with reference to early childhood children.

Purposes of On-Going-Thinking Model

The purposes of the On-Going-Thinking Model are to encourage early childhood children to:

1. Participate in making their intuitive and prior knowledge of the learning model context explicit in a variety of settings through a variety of means: through individual contemplation, small group discussion, whole class discussion, writing, drawing, model making. This emphasis on participation assists young children who cannot yet write or read well, or who are too shy to expose their ideas for a whole class inspection, to participate without pressure, without fear of being neglected, and in ways that attend to individual needs.
2. Use their ideas and the ideas of others to generate additional ideas, some of which they may wish to test, either alone or with friend(s).
3. Reflect on their ideas continuously: by discussing them with others; by noting how they compare or contrast with the ideas of others; by keeping records in the form of drawing, or writing; by having their ideas recorded by their teacher.
4. Help others to learn and welcome the help of others if needed. This purpose of the model builds into it the Vygotskian understanding that children should be assisted at first to accomplish something by a more competent peer or by their teacher, that later, they will accomplish alone.

The model has five phases which are depicted below.

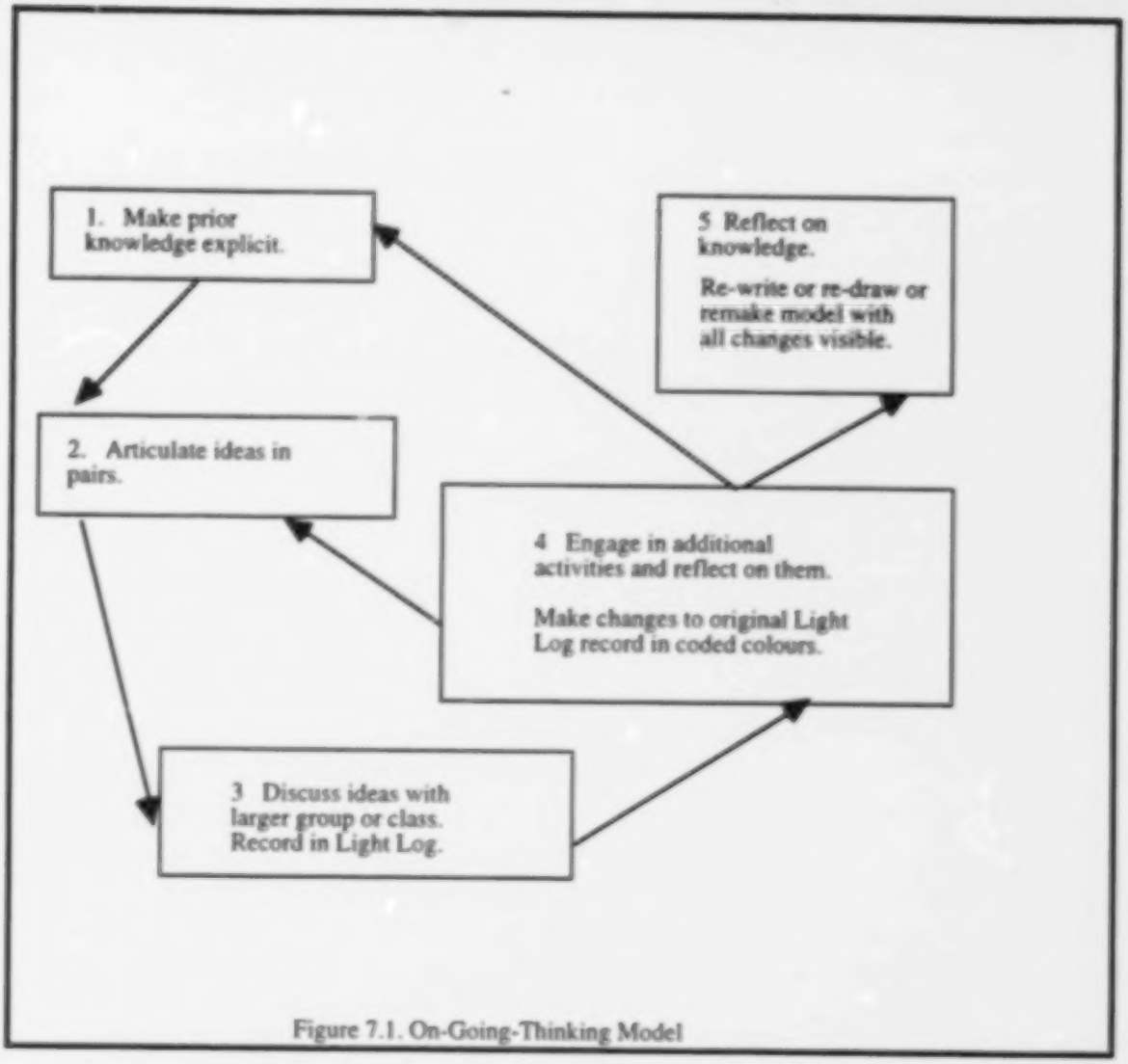
1. Make prior knowledge explicit.
2. Articulate ideas in pairs.
3 Discuss ideas with larger group or class. Record in Light Log.
4 Engage in additional activities and reflect on them.
Make changes to original Light Log record in coded colours.
5 Reflect on knowledge.
Re-write or re-draw or remake model with all changes visible.

Figure 7.1. On-Going-Thinking Model

Although the phases of the model are numbered sequentially, they are not meant to be read as an unalterable sequence, nor even as separate from each other. Neither are the phases equal in time. We designed the model to accommodate the learning styles and preferences of all children in the class, through its multiple teaching strategies, and learning and reflective opportunities. This plurality of method and epistemology, we assumed, would make the model inclusive of children of varying ages and gender provided that the learning model context was itself inclusive and the teacher was sensitive to issues of inclusion.

In retrospect, our model resembles a blend of some features from the interactive teaching approach of Biddulph and Osborne (1984) and some aspects of the approach taken by the designers of the Primary SPACE project (Osborne et al., 1990). The On-Going-Thinking Model shares with both models the central idea that children need to be engaged by the science context. Then they can be encouraged to articulate their thoughts about the context, often in conversation with others. While our model retains from the interactive teaching approach, a possibility that children might be

helped to articulate and then find answers to investigable questions, this is not its central feature. As with the learning model used in an earlier study (Segal, 1994) *informal inquiry* describes this aspect of generation and testing of ideas more closely (for early childhood children) than does articulating investigable questions. A major design feature of our model is that it provides children with many opportunities for reflection, including using a personal learning journal that we called a Light Log. (The use of a Light Log for reflective purposes for children and as an aid for teachers' understanding of children's developing ideas has been justified elsewhere (Segal & Cosgrove, 1995). This emphasis on reflection is shared with the cycle of teaching steps of the Primary SPACE project.

Research Schedule and Data Sources

The table below summarises the research schedule of this study, its connections to the Associate Teacher Program and the Whole School Professional Development Program and indicates sources of data. The early part of the research schedule, in which I regularly visited the classrooms of the teachers, is not shown in the table.

Table 1: Outline of research schedule and collection of data

Date	*Activities as part of Associate Teacher Program (ATP) and sources of data*	*Activities as part of Whole School Professional Development Program and sources of data*
5-6/93	Eight sessions (22 hours) staff development and Light Unit planning/writing (audio tapes).	
6/93	Interviews with Associate Teachers to gain further information about children in classes (audio tapes).	Three weekly after-school sessions (audio tapes).
14-15/6/93	Colleague Teachers and I prepared a motivational Light Room - all classes visit and discuss ideas about light (field notes, video and audio tapes).	Conversations with researcher whose study in part, was also carried out in classrooms of Colleague Teachers (field notes).
11-25/6/93	All teachers conducted extended lessons (from one to two hours), sometimes two in one day (field notes, video and audio tapes; children's Light Logs, still photographs of children at work, large chart record of class-brainstorming sessions; copies of teacher-prepared worksheets). Conversations with teachers after some lessons (audio tapes). Researcher informed me of her conversations with Colleague Teachers about my research (field notes), with their permission.	
25/6-12/7	School holidays	
7-8/93	I was absent from Australia in July and had University teaching obligations in August. Teachers agreed to re-commence teaching Light Unit, when I could visit all classes.	
8/93	Interviews with about half the cohort from all classes, in small groups of two or three children (preparatory notes, video and audio tapes).	Sessions continued, but I was not involved due to teaching commitments at University.
8/93		Colleague Teachers and I presented our findings on the Light Unit so far, to whole staff (video and audio tapes).

Table 1: Outline of research schedule and collection of data (continued)

Date	*Activities as part of Associate Teacher Program (ATP) and sources of data*	*Activities as part of Whole School Professional Development Program and sources of data*
27/8-15/9	All teachers conducted extended lessons (field notes, video and audio tapes; children's Light Logs). Conversations with teachers, researcher and a few parents (audio tapes).	
9/93	Teachers and I met to discuss and evaluate Unit (preparatory notes, audio tapes).	
11-12/93	Interviews with all children from the three classes, in small groups of two or three children (preparatory notes, video and audio tapes).	
12/93	Teachers and I met to discuss Unit (preparatory notes, audio tapes). Biographical information about teachers (written and audio tape)	Conversations with researcher, after viewing some of our video tapes (audio tape).
1993-94	Presentation of preliminary findings at internal research seminars and conferences. Discussion of interpretations with other researchers (field notes and audio tape).	
6-11/95	Mrs. C. and School Principal read first and final drafts of research description in my thesis. They agreed with factual and interpretive material (Written note and phone conversations with Mrs. C.)	

In the sections that follow, I first describe some lesson activities in conjunction with analysis of those activities to assist depiction of the phases of the learning model in action. Then I examine on a wider basis, mediational means by which children appropriated, in varying ways, an understanding of shadow formation.

THE LEARNING AND TEACHING MODEL IN ACTION

Mrs C. was eager to begin the Unit. She seated the class in front of her on a carpet and began to read them an exciting adventure story *In the Middle of the Night*. There were many lights and shadows in the pictures from the large book that she displayed for class inspection as she read.

Phase One: Making Prior Knowledge Explicit

Mrs. C. encouraged children to tell her what they noticed about the story and the pictures. She listened patiently to all responses, even to the extent of allowing one shy child to come to the front to slowly turn over all pages in the book to find the picture she had in her mind. Gradually, Mrs C. guided the discussion to centre on light and shadows, thereby allowing children to make their prior knowledge explicit in the context of the story. This section analyses four factors in the first class discussion in the Unit that helped in this process.

1. The discussion was set in a pleasurable story-telling beginning that integrated science and technology with language.

If a class discussion is to provide opportunities for children to express their prior ideas, a teacher must feel that she has sufficient time to allow many children to make contributions. The introduction of the Light Unit through a story, made that time available from time normally allocated to Language teaching. Mrs. C.'s choosing to begin the Light Unit with a story was effective for stimulating discussion for other reasons too.

1. The class enjoyed listening to stories, especially mystery stories like In the Middle of the Night that are accompanied by evocative pictures; a positive affective response to the light and shadows context and to the ensuing class discussion could be expected in most children.
2. The story created links between children's enjoyable activity of reading at home and school activities. Many contributions to discussion might therefore be expected, thereby concretising learning (after Wilensky, 1991). One such home-school link was made explicit by Laura (Year 1) who explained to the class that she had a book called *In the Middle of the Day* at home. She explained similarities and differences of the covers of the two books at some length, revealing in the process, some of her knowledge about day and night.

2. Mrs. C. provided a variety of openings for many children to enter the discussion.

By asking children questions such as "What did you notice?" after reading *In the Middle of the Night*, Mrs. C. indicated to her mixed-ability and mixed-grade class members that a wide variety of responses was acceptable. No-one was excluded by question difficulty. Most indicated by up-raised hands, that they wished to contribute their ideas and wanted to tell Mrs. C. and the class something about the book, the story, or the pictures. In all, 22 of the 30 children made a contribution to this initial class discussion, with some children being called upon more than once.

3. Mrs. C. and the class listened carefully to children's contributions without rushing the speaker.

By listening actively to children's responses, Mrs. C. inquired into children's meanings of their contributions, thereby assisting children to articulate their meaning more clearly so that she, as teacher, and other children could make sense of what was being said. This close attention to children's contributions was another facet of the respect that marked Mrs. C.'s interactions with the children in her class. In this case, her close attention showed her respect for children's ideas.

Mrs. C.'s inquiry into the meaning of children's responses necessitated a slow lesson pace. That slow pace and the attentive silence that greeted each child's contribution helped to create a supportive classroom learning environment. This environment encouraged children to contribute their ideas, to make themselves understood and if necessary to disagree with Mrs. C.'s interpretation of their meaning. In addition, the attentive silence accorded each contributor probably encouraged very shy children to state their ideas.

4. Mrs. C. and the class began to build common knowledge

The factors mentioned so far - time for discussion, beginning with a story that promotes home-school links, Mrs. C.'s encouraging many contributions and listening to each child with respect helped the class build a pool of common knowledge (after Edwards & Mercer, 1987). The continued discussion kept reminding children of their knowledge and they were keen to add their ideas. A rich resource from which later transformational interactions and investigations could emerge was under construction.

An example of how Mrs. C. used children's contributions to class discussion as a source for elicitation of prior knowledge and further thinking occurred towards the end of the first class discussion. When Mrs. C. re-focussed children's attention on shadows, she continued:

Mrs. C.:	Just think about the light for a minute. Put your hands down. I'm going to turn over the pages and somebody mentioned before light sources and they also mentioned shadows. Who was that? Andrew wasn't it? All right, have a look. Can you see the light source?
Class:	Yes.
Mrs. C.:	Can you see a shadow? How about this page?
Class:	Yes, yes.
John:	It's blocking it.
Mrs. C.:	Sorry John?
John:	It's blocking it.
Mrs. C.:	What is blocking what? *(Helping John to clarify his meaning)*
John:	Um. The oar - it's blocking it, so um,
Mrs. C.:	Blocking it? What's it? *(Providing John with further assistance)*
John:	The paddle.
Mrs. C.:	Yes, but what's blocking? Blocking? *(Now assisting John to clarify the meaning of blocking, so that everyone in the class is able to understand exactly what he means)*
John:	Blocking the light from the moon, so it's making a shadow because the paddle's on the path and it shines on the paddle so it's sort of like cutting out the shape.
Mrs. C.:	Well that's interesting what John has just said. We'll come back to that, we'll come back to that because I want to let people see some of the other pages and just see if there are shadows there, and the lights are there.
	(Lesson 1, class discussion)

Unexpectedly, while Mrs. C. was turning over pages, she heard John, (Year 1) sitting in the front, say "It's blocking it" in a soft voice. The picture on the page showed moonlight streaming down towards a rowing boat and oar, with the dark shadows clearly drawn behind the boat. Moonlight not blocked by the boat and oar was shown streaming on, unimpeded in its path. As John said, the light shining on the paddle looked as though "it's sort of like cutting out the shape." The clarity of the picture could have prompted John to think of the idea of shadows formed by blocking of light.

John's contribution to the class discussion, "It's blocking it" is an indication of his intellectual engagement in the context of the story; when he spoke, he carried the class discussion to a deeper level, as at that stage, Mrs. C. had not asked children to interpret pictures in the book, only to describe them.

Mrs. C. developed the emergent thinking to a deeper level and at the same time included the class in the context by asking for elaboration of John's language and meaning. First, she sought meaning for "it" and "blocking", then a little later, she asked him to come out to the front to repeat his idea. As with other children to whom she listened with sensitivity, it is probable that by paying attention to John's idea like this, Mrs. C. helped to enhance his self-esteem and confidence in articulating his ideas; at the same time, she skilfully laid foundations for developing class common knowledge about a way of interpreting shadows.

Phase Two: Articulating Ideas in Pairs

Mrs. C. continued Lesson 1 by explaining to the children what she wanted them to do next.

> Mrs. C.: I would like you to, in a moment, (*children were looking around, to catch their friend's eye)* discuss with someone else near you, wait, wait, wait, wait *(as children began to move)*. Two things. Two things. You can talk about light sources that you might have seen in this book and other light sources you know and also, you can talk about shadows and see whether you think what John said is true - that he thinks that when the light is blocked, then the shadow is formed. All right, you discuss with someone else.
> (Lesson 1, class discussion)

The eagerness with which children began to seek a partner is indicative of their prior experience with this teaching strategy, and their previous enjoyment of it. Mrs. C. did not indicate whether she agreed or disagreed with John's idea. Her invitation to the children to discuss it, modelled a scientific process of suspending judgment until the full implications of an idea could be considered. However, mindful that many children might be at a loss to understand John's meaning, her first option for discussion in pairs was a general and open topic of conversation: their ideas about light sources and shadows that could stem from their general knowledge or from observations made from the book.

One pair discusses John's idea

I watched one pair and then spoke to them, while the class was engaged in this phase of the On-Going-Thinking Model. Colin and Barry, (both Year 1) were deliberately drawing each other's attention to the shadow beneath their hands, but had not articulated any understanding of that situation before I began to speak to them.

Gilda: How do you think that shadow got there? *(referring to a shadow underneath Colin's hand, held close to the carpet)*

Colin: 'Cos there's lights up here. *(pointing to the ceiling)*

Gilda: And then what happened?

Colin: It's actually like what John said.

Gilda: Yeah. Can you explain that again with that shadow of your hand that you just found?

Colin scratched his head, looking a little puzzled.

Barry: 'Cos you're blocking the light.

Gilda: How did the light get there to be blocked though?

Barry: It's on the ground.

Gilda: But isn't the light up there? (*pointing to the ceiling*)

Colin: Actually we're in the middle of the light, so *(he looked around, but his voice tailed off)*

(Lesson 1, interview with Colin and Barry)

In response to my next question, "Where is light in this room?" (after Guesne, 1985), Barry and Colin like children in Guesne's studies, then identified light with its sources - on the ceiling, outside the windows and glass doors.

Gilda: So which light is being blocked?

Colin: I think it might actually be both of these (*pointing to window and ceiling)*

Barry: I think it might be that one *(pointing to the ceiling light above him).*

(Lesson 1, interview with Colin and Barry)

In this interaction, Colin and Barry attempted to apply John's idea about shadow formation to another context, the shadow underneath their hands. My questions about their exploration left them poised on the brink of understanding some aspects of shadow formation: that light is blocked to form a shadow (Colin and Barry); that a source of light is responsible for light being present (Colin and Barry); and that "we're in the middle of the light" (articulated by Colin). The interaction is an illustration of the fragile beginnings of appropriation of a scientific idea of shadow formation and perhaps that light travels from source to object. Some of that understanding was being constructed by both boys, but was not as yet, fully internalised by either. In the terms of Newman, Griffin and Cole (1989), this is appropriation of science outside the skin. Final interviews with these boys indicated that Colin did not internalise the idea that a shadow is formed when light is blocked, but that Barry did.

In summary, use of the first two phases of the model led to John's contribution to class discussion, Mrs. C.'s suggestion that children discuss John's idea and to Colin and Barry's exploration of John's idea of shadow formation in a different context. These aspects, together with my participation in conversation with Colin and Barry were part of the mediational means by which Colin and Barry began to appropriate the concept of shadow formation. As I had not conversed with these boys before about their views on shadow formation, I do not know if John's statement

articulated with their existing knowledge about shadows, or whether his idea was wholly new to them.

So far then, this Learning and Teaching Model, developing through sensitive teaching, has supported most children in contributing to class discussion in Phase One and has encouraged all children to express their ideas to a peer in Phase Two. Judging by the enthusiasm with which children turned to each other, this option was one they enjoyed.

Phase Three: Whole Class Discussion

As for Phases One and Two, a purpose of Phase Three was to allow children a further forum to articulate their ideas and make them public, and thereby to establish a pool of common knowledge on which children could reflect during the Unit and use as a source of further ideas.

Class discussion resumed, with children adding information about shadows and light sources from their activities and knowledge outside of school; some made it clear from their contributions that they had discussed John's idea. For example, Carlie (Year 1) stated that light from the window was blocked when shadows were formed; thus she added to John's idea in public. Gerard, (Year 1) then explained the shape of a shadow by using a metaphor of cutting out identical shapes by folding a piece of paper.

Gerard:	You know when you have a piece of paper and you want to cut out a shape and you want to have two? Well if you fold it over and you cut out a shape, when you have two shapes, when you've stuck one on a piece of paper and you still have another one, well you have to shine it over the other one it actually looks like it's a shadow, 'cos it's got two exactly the same.
Mrs. C.:	Are shadows always the same? As the actual object?
Gerard:	Well, no.
Class:	Not always.
	(Lesson 1, second class discussion)

For the first time, Mrs. C. gently questioned a child's contribution, asking children to think about evidence for Gerard's generalisation. Gerard and the class realised that he had made an analogy that did not stand up to close scrutiny. A small signal to children of the value of both questioning generalisations, a value highly important in science education, and of a process that Schön (1992) calls *reflection-in-action* entered this emergent context.

Reflection-in-action

Mrs. C., in responding to Gerard, needed to *reflect-in-action*, that is, she needed to make quick sense of Gerard's contribution to discussion in a situation where she had no inkling of what he might say. As Schön (1992) explains this process:

> Reflection-in-action is an ephemeral episode of inquiry that arises momentarily in the midst of a flow of action and then disappears, giving way to some new event, leaving in its wake, perhaps, a more stable view of the situation. (p. 125)

It is necessary to distinguish, as Schön has done, reflection-in-action from the more common meaning of reflection, that involves "turning thought back on itself" (p.126) or as cited by Schön, a "stop-and-think" of Arendt (1971). A stop-and-think kind of reflection might involve a teacher asking herself in a deliberative fashion, the meaning of a child's earlier response, or a teacher might seek to analyse her teaching behaviours that have become automated. Reflection-in-action, on the other hand, "reshapes understanding in the midst of action" (Schön , 1992, p. 126).

I suggest that Mrs. C.'s ability to reflect-in-action is an important component of a model of learning and teaching like the On-Going-Thinking Model that has an aim of assisting children to reflect, in both senses, in- and on- their actions and their thinking. Mrs. C.'s reflection-in-action in this episode and in many such episodes, is a repeated tacit message to children that they too, should and can analyse the meaning of events and the contributions of others to classroom discourse.

Recording knowledge

After listening to a few children's ideas that arose from discussion in pairs, Mrs. C. explained to the class that she planned to record their ideas about light and shadows. She produced a large piece of white paper, on which she had drawn a picture of a globe, (with a clearly drawn filament) enclosed within a light shade. Taping it to the blackboard, she began to record class knowledge on the paper.

Mrs. C.: Hands down for a minute. This is something I did yesterday.
Children: It's a light.
Mrs. C.: Yes it's a light. It's a light source .... I want anything you might know about light, light sources and about shadows. Anything that you would like me to write up there. Anything you would like me to say at all. It can be words. It can be words about light and light sources. It can be a sentence.
(Lesson 1, second class discussion)

As in Phase One, Mrs. C. encouraged the children to make contributions on any level that they could (words, sentences, light, light sources, shadows.)

Mrs. C.: Anything you'd like me to write up. Um, Sarah.
Sarah: If you don't have light, you can't have a shadow.
Mrs. C.: Oh, that's an interesting one. Let's write that one up. If, this is what Sarah thinks, if you don't have light, tell me if I'm right, Sarah. If you don't have light, you can't have a shadow?
Sarah: Yes.
(Lesson 1, second class discussion)

Mrs. C. listened to children's ideas and checked that she was expressing their ideas correctly, as she wrote them down. This emergent context continued to develop through children's thoughtful contributions and Mrs. C.'s meticulously paying attention to what the children were trying to say. The result was not just a pool of prior knowledge, but prior knowledge whose meaning had been shared and negotiated by the teacher with the original contributor.

Building shared meaning

On rare occasions, in the process of trying to record a child's contribution, Mrs. C. omitted some words that altered the scientific meaning of the child's statement. Children were alert, reflected-in-action and added the appropriate words to restore the meaning of their proffered contribution, as in the exchange below with Jamie (Year 2).

Mrs. C.: Jamie.
Jamie: Well, when, like when the light's coming, then, when the shadow's like, there is this sort of like, wherever you go, the shadow will go.
Mrs. C.: Where you go, the shadow goes with you. Is that right?
Jamie: Yes. You have to have a light. *(Here Jamie corrected Mrs. C.'s representation of his statement to restore its scientific meaning, that light is needed for shadow formation).*
Mrs. C.: Well hang on. If there is light, now what did you say now, where you go the shadow goes. Is that it?
Jamie: Yes.
Mrs. C.: If there is light, where you go, the shadow goes. Is that right Jamie?
Jamie: Yes.
(Lesson 1, second class discussion)

During such interactions, building class knowledge was dependent upon children's and Mrs. C.'s cooperation in establishing the meaning the children intended to convey by their statement. The next conversation between Mrs. C. and Jimmy (Year 1) illustrates further this critical role played by Mrs. C. as she carefully assisted Jimmy to articulate his ideas for publication in complete sentences.

Jimmy: Well um, with the shadow, see how my hand is there,
Mrs. C.: Yeah.
Jimmy: Well, it's taking, like the light's up there, and the, it's taking the light away, it's on, it's on my hand.
Mrs. C.: So how, just say a sentence so I can write it up.
Jimmy: Well, um, when you have a light and you put something over it, and the shadow under it, taking the light.
Mrs. C.: So when you have light, that's a good sentence Jimmy, give it to me again.
Jimmy: You put something over it, taking the light on top of it, like,
Mrs. C.: OK, hang on. And you put something over it,
Jimmy: taking the light, so,
Mrs. C.: it takes the light

Jimmy: so there's no light underneath, so it leaves a shadow.
(Lesson 1, second class discussion)

Jimmy's first statement of shadow formation was not as clearly explicated as John's original statement "It's blocking it." Jimmy did not use the word blocking; instead he used the more active word *taking*. Mrs. C. retained his words, but encouraged him to formulate a complete sentence. The statement Jimmy and Mrs. C. constructed together is an example of guided participation, with Jimmy and Mrs. C. having an equality in partnership to accomplish a goal (Rogoff, 1990). The child in this case was encouraged to offer the explanatory side of the contribution; the teacher offered help to express the explanation more clearly. This careful attention to children's expression of their thoughts had some additional advantages for children's learning: It allowed time for class members to better understand what the child was trying to say and it offered opportunities to improve their reading and spelling, as they watched Mrs. C. record the words she was repeating aloud.

Children continued to add information about shadows and sources of light, waving their hands in the air, when Mrs. C. called for the next contribution. A few contributions were general: "Shadows are easier to see at night than in the day" (Kylie, Year 2); "Shadows are always black" (Gina, Year 2).

Change in the nature of class discussion

In the early parts of the discussions reported here so far (all taking place in Lesson 1), children listened silently to others as each child contributed ideas and interacted with Mrs. C. The first sign of change in discussion format came towards the end of the discussion in Lesson 1. Andrew suddenly volunteered that he disagreed with Kylie's statement that "shadows are easier to see in the night than in the day, because the moon reflects down to the shadow". This was the first instance of many recorded in later lessons, where children first listened to each other's ideas and then preceded their own contribution by an explanation of whether they were adding to another's idea or disagreeing with another's contribution, or offering a contribution that had nothing to do with the previous discussion.

Andrew: I don't really agree with Kylie.
Mrs. C.: Well that's all right, this is all just people's ideas. Some of them might be right, some of them might be wrong.
Andrew: You know that park where we used to go down to, near *(inaudible)*
Mrs. C.: Yes.
Andrew: When you *(inaudible)* for a minute, then your shadow is bigger than yourself, and it looked better in the morning than night. And shadows, when you can never change a shadow's colour.
Mrs. C.: I'll write it here. Andrew disagreed. I don't have room to write all that up Andrew. Andrew disagrees but, did you say a shadow can't change colour?
Andrew: Yes.

Alison: That's like Gina said, A shadow's always black.
(Lesson 1, second class discussion)

Andrew's statements are interesting for five reasons:

1. This was the first example of a secondary level of engagement in class discussion, where a child interacted directly with another child's contribution. That Andrew disagreed with Kylie's statement, (that shadows could be seen more clearly at night) indicates he was thinking about the meaning of her contribution and comparing it to his experience. Such a comparison is indicative of intellectual engagement in class discussion, through reflection-in-action, (recognising that his opinion differed from Kylie) and reflection-on-past-experience (thinking about how his observations of shadows in the park at different times of the day contradicted Kylie's claim).
2. Andrew not only disputed Kylie's statement, but explained why he disagreed. He contrasted his own observations of the darkness of the shadow as seen in the morning, with his observations of the darkness of his shadow at night in the same park ("it looked better in the morning than night"). His report is similar to one of a controlled experimental test of the influence of time of day on darkness of his shadow. Here Andrew has kept the person, location and conditions constant, varied the time of day, and inspected the darkness of the shadow.
3. He introduced new knowledge by informing the class that the length of shadows varies throughout the day.
4. His tone of voice conveyed that he disputed what Kylie said, not that he wanted to diminish Kylie herself or her right to make a contribution. This lack of personal unpleasantness was another feature of all subsequent challenges by children to what others had said. My interpretation of this lack of personal unpleasantness is that it is related to the respect accorded all children in the class by Mrs. C and to the children's upbringing (but this is conjecture).
5. By the way Andrew referred to the park, it appeared that the park was known to teacher and class. Andrew's contribution is important in the context of this research, as it was one of several examples of a child's bringing the outside world into the classroom through relating personal experience outside the classroom. Hence this context meets one of its design criteria, familiarity, and helps to make early learning at school seamless with learning out of school.

These five features highlight features of an emergent context, constituted through interactions between Mrs. C., her class and the On-Going-Thinking Model that may be considered as mediational means for development of children's ideas in the learning model context of light and shadows. In addition, there are two other features within this short excerpt that indicate how children were developing their ideas and subjectivities, and the potential for their further development.

1. Children began to initiate discussion, through first Andrew and then Alison making contributions without being called upon to do so.

2. **Even after such a prolonged (40 minutes) discussion, Alison was alert and following proceedings, and she was able to link Gina's statement, that shadows are always black, with Andrew's contribution that a shadow can't change colour. She too reflected-in-action.**

In brief, all seven features support my assumption that light and shadows is a familiar, inclusive learning model context that has the potential to engage children through dialogic exchanges that develop their ideas about the context and to help them to reflect on their ideas.

Preparing children to reflect on class discussion

Phase One of the On-Going-Thinking Model provided material on which children could reflect during their pairs discussion in Phase Two. Now in Phase Three, Mrs. C. was compiling a written record of children's ideas upon which children might reflect further during the Unit. As she wrote, she conveyed ownership of ideas by a statement such as "This is what Kylie thinks", and by attaching the child's name to the statement on the class record of prior knowledge. Mrs. C.'s first subtle indication that the record of ideas was material for reflection, was contained in her statement that some ideas might be right and some might be wrong. When the record was completed, she softened the finality that children might have read into that statement by reassuring children that their ideas may change in time and without penalty. As she gestured to the chart of ideas, she stated: "In the next few weeks we're going to do a lot of things and we may want to change our minds." Through this statement, Mrs. C. conveyed first that the knowledge statements recorded on the chart belonged to the class, as well as to the individuals who first suggested them and second, that they could be regarded as worthwhile, but tentative, open to change in the face of later activity and reflection.

Helping children to reflect: Using their Light Logs

Children made their first entries in their Light Logs in Lesson 2. Most children chose to draw and write about their ideas appropriated during that morning's discussion. Most children wrote one or two sentences, but Rachel (Year 2) wrote a little more (original spelling and punctuation retained).

> I learned that lights can be different shapes and sizes. Lights can be different colours if you put coloured paper. lights *(sic)* can make shadows and if you don't have a light you don't have a shadow. A light has a fin - the part that hangs in the middle - when it breaks the bulb runs out. Lights are interesting. (Rachel, Year 2, Lesson 2, Light Log)

Some children's first entries were inspired by the experimental tests of shadow-making that they carried out while making their source collages. Children showed me their shadows underneath their hands but most, in spite of John's earlier statement and their subsequent invitation to discuss it, were at a loss to explain how the shadow was formed. Jack (Year 1) wrote about this experience (original spelling retained): "I lerned that if thair is a lite a buv yor hand then et makes a shadoe."

Thus far, discussion excerpts have shown that the emergent context, mutually constructed by Mrs. C. and children during implementation of the On-Going-Thinking Model, assisted both children and Mrs. C. to appropriate ideas about sources of light and shadow formation and to reflect on these ideas in two main ways through:

1. Class discussion, during which Mrs. C. and children increased the complexity of contributions by commenting on each other's ideas, thereby conducting transformational interactions. This process subtly initiated a demand on teacher and children to reflect-in-action quickly and to reflect on reflection-in-action, to accommodate what they were about to say, to what had been said by other people.
2. Follow-up activities to class discussion: pairs discussion; an activity to exemplify discussion (finding sources of light in magazines); writing and drawing in the Light Log.

The chart of class knowledge and children's drawings and writing in their Light Logs provided an indication of appropriation of ideas about the learning model context of light and shadows that had been mentioned by one or more children to that point.

Phase Four: Further Activities and Reflection

Implementation of Phase Four illustrates further aspects of contexts that emerged in this study. The first aspect concerns children's generation of questions and testing their ideas; the second illustrates how children's inquiry in Lesson 14 became the material for reflection and appropriation of ideas during class discussions that followed their investigations, in Lesson 15.

Further activities: Inquiry through generating questions and testing ideas

During a class discussion, (Lesson 11), Mrs. C. encouraged children to generate some questions that they might like to investigate in subsequent lessons; children readily volunteered suggestions. Mrs. C. recorded the questions and children could then choose which of these question(s) to investigate, (or they could generate their own). They could also choose whether they wished to work alone or with a partner in Lesson 13.

Some investigations were ingenious; for example some children investigating the question "Does water have a shadow?" tried to throw water on the ground and watched for its shadow before it landed. In the following lesson (Lesson 14), Carlie asked me to come over to watch her experiment, emphasising that she needed me to come to her, as her experiment required special conditions of an overhead roof and a shaded place. She was investigating the question: Does water reflect light? (There had not been any class discussion about reflection or about how children might test to see if reflection was occurring.) Not only was she shining the flashlight at an angle so that it might reflect off the surface of the water, she had put her bucket in the darkest place she could find under a verandah and was looking for the reflection on the undersurface of the verandah above the bucket. Unfortunately, the combination of a fairly weak flashlight, a high roof and too

much ambient light meant she did not see any reflection. She concluded therefore that the water surface did not reflect light.

Class discussion after inquiry: 1. Mrs. C. models how to organise data

Children were very quick to sit down when they came into their classroom for Lesson 15 from the playground after recess. My impression was that they wanted to share their observations and ideas with the class, after carrying out investigations of questions suggested by class members in Lessons 13 and 14.

Mrs. C.: Who's got something interesting to say? Does everything have a shadow? *(One of the class questions).* I thought it was very interesting about what Terry said about your heart - it doesn't have a shadow because it doesn't have a light source in there. Are you sure it doesn't have a light source? What about if I open my mouth? Carlie has something to say.

Carlie: When I was outside,

Mrs. C.: Yes.

Carlie: I did this. *(Inaudible)* I had to put it in the shade, I got a bucket full of water and then I got a flashlight and shone it over the bucket,

Mrs. C.: Yes.

Carlie: *(Inaudible)*

Mrs. C.: Does water have a shadow? or Does light reflect off water? Which question?

Carlie: Can light reflect off water?

Mrs. C.: And Carlie thought "No" here, is that right Carlie?

Carlie: Yes.

(Lesson 15, class discussion)

As I had watched her perform this experiment, and was very impressed with what she had done, I interrupted the class discussion (something I did very rarely) to suggest that Carlie explain in more detail to the class. This she did. Children's interest was sparked, but Mrs. C. was actually in the middle of recording on a large chart, reports from investigators of the question "Does water have a shadow?" when Carlie made her original contribution. Mrs. C. preferred to continue asking for contributions from children who were investigating "Does water have a shadow?" as she made clear to children who wished to comment on Carlie's contribution.

Terry: Can I say something about Carlie's?

Mrs. C.: Wait just a second - does anyone have anything else interesting about this one? *(Does water have a shadow?)* Jamie?

Jamie: I want to put something onto Carlie's.

Mrs. C.: Just wait a second, I want to deal with this one, OK. Does water have a shadow? Somebody might say no. Somebody else may say yes because of a different thing. Kylie.

Kylie: No, because um, because the sunlight reflects *light*, so there's no shadow. So the shadow disappears.

Mrs. C.: No, because the sunlight, What did you say?

Kylie: Because the sunlight reflects light down onto water so there's no shadow.
Mrs. C.: Reflects light down onto water, Is that right? So there is no shadow. Is that right?
Kylie: Yep.
Mrs. C.: Has anyone got anything else about that particular question before we go on? (Lesson 15, class discussion)

Occasionally, as here, with so many children anxious to tell Mrs. C. about their own experiment, Mrs. C. did not draw out each child in her accustomed manner, so it is a little unclear how Kylie was picturing the orientation of the water and the sunlight. Many children outside had been trying to find out if water had a shadow. Some were using flashlights, so it is possible that Kylie was trying to say that the light of the sun was making it impossible to see the shadow of the water. Another complication lies in her use of the word *reflect*. By *reflect down*, many children simply mean *shine*. Another possibility is that she may have meant that shadows cannot form without some kind of screen.

Mrs. C.'s decision to deal with one question at a time, modelled for children a very important skill in science, that of organisation of data. Children had many opportunities to observe Mrs. C.'s way of dealing methodically with the ideas that they suggested during class discussion. An example of a child's appropriation of this understanding comes from Terry's inquiry before making his contribution, whether it was an acceptable contribution at that time (Can I say something about Carlie's?).

It was clear from both Terry's and Jamie's contributions that they were eager to add their ideas to Carlie's description of her experiment. There were now, however, details of two experimental observations and investigations in front of the class, Kylie's and Carlie's. Children were keen to participate in discussion about both, but Mrs. C. kept the focus on discussion of the question: Does water have a shadow?

Class discussion after inquiry: 2. Intellectual engagement with the ideas of others

After hearing from two other children who added their ideas about Kylie's experiment, Mrs. C. nominated Sarah.

Mrs. C.: Sarah?
Sarah: Well if you hold a piece of paper over the water then the sun can't get to it. (*Sarah was referring to Kylie's inference that the sunlight reflecting down interfered with shadow formation.)*
Mrs. C.: So hold a piece of paper, maybe I should put it here, to look at next time. *(Mrs. C. was making a separate list of unresolved questions and suggestions for future experiments for resumption of the Unit after the holidays.)*
Sarah: Hold a piece of paper over some water then the sun can't get to it. As Kylie said, water um can't have a shadow because of the sun, and we don't know because we haven't held a piece of paper over water. (Lesson 15, class discussion)

Sarah added to Kylie's statement, by suggesting an experimental test of Kylie's hypothesis, that water does not have a shadow because of the presence of the sun. She extended her argument, by emphasising that unless the change that she suggested was made, and unless the question was experimentally investigated it was not possible to answer the question. Like other children, her growth in fluency in her expression of her thoughts and the ever-deepening intellectual nature of those thoughts became apparent as the children's experience in the learning model context increased.

Sarah's contribution was followed by additional suggestions from Kelly, Nancy and Sarah herself, that compared their container of water outside to water in a pool or at the beach. The children described how water sparkles in the sunshine and speculated that no shadows could be seen because of the sparkling conditions. This was one of a number of instances of children's engagement in transformational interactions, where children added to other children's contributions, indicating the attention they paid to each other's ideas. Mrs. C. recorded their ideas on her chart, then allowed Andrew to make a comment on Carlie's contribution.

Andrew:	Can I add something to Kylie, I mean Carlie?
Mrs. C.:	Yes.
Andrew:	Well you can reflect light off water, 'cos um, water does reflect. When I was *(inaudible)*. If you put a bit of coloured cellophane over it, it will reflect, and it will reflect.
Mrs. C.:	All right Andrew, you'll have to think about whether you needed coloured cellophane, then, won't you, to show it.
Sarah:	No you don't need it.
Mrs. C.:	Maybe you used coloured cellophane. All right. All right anything else? Can light reflect off the water? Thank you Andrew, Terry?
Terry:	I want to add on to Carlie's. It wouldn't have reflected because she was down in the toilet area. It's quite hard to get a reflection that's outside.
Mrs. C.:	So perhaps Carlie was in too light a place? Right, thanks Terry.
	(Lesson 15, class discussion)

Andrew seemed sure that water reflects and suggested that using coloured cellophane (probably over the flashlight) would prove his idea; Mrs. C. advised him to think more about this proposal and Sarah, still following the conversation, thought the cellophane would not be needed. Terry, who had earlier indicated he wanted to make a comment on Carlie's experiment offered a plausible explanation for the reflected light not being observed, that there was too much light to observe any reflection from the surface of the water on the high ceiling above. He was one of a number of children who had observed Carlie's experiment outside. Children continued to offer suggestions and advice to others.

In summary, this class discussion, an aspect of Phase Four of the model, illustrated:

1. Mrs. C. modelling for children how to organise collection of data through her insistence on discussing answers to one question at a time; children's appropriation of this process, and their collaboration to keep the process orderly.
2. Ingenious experiments that young children devised to test their ideas, and the interest that children had shown outdoors in the experiments of others.
3. Deep and thoughtful intellectual engagement of the children with contributions of others, with children adding experimental suggestions for checking the conclusions of others and suggestions that might explain unexpected observations or lack of observations.

The dividends for Mrs C.'s skilful teaching were paid in class discussions such as those above, where there were many examples of children interacting directly with each other's ideas.

Phase Five: Reflection: Short term and Long Term

Phase Five of the Model, acting in concert with the other phases was designed to provide children with time to reflect on what they had learned and to continue to develop ideas and questions about the learning model context. In this section, I shall discuss three examples of children's reflection on their learning: the first and second examples occurred after the class discussion reported above in Lesson 15, the third is an example of a child's reflection about the answer to her own question over the five months of the Unit.

Jimmy reflects in public

During the class discussion in Lesson 15, many children showed through their contributions that they were reflecting-in-action; some showed they were reflecting on thoughts and actions, either of their own or of others. Some children like Jimmy, who had not said anything about the questions previously, were able to sum up the ambiguities of the answers of other children to the question "Does water have a shadow?", as can be seen in the conversation that follows.

Jimmy: Well, sometimes, with the water, sometimes it can have a shadow, sometimes it can't. When you put a piece of paper under the water, it does have a shadow on the paper, but if you don't have a paper, it doesn't have a shadow [on the paper.] If the water is clear, the sunlight goes right through it.

Mrs. C.: Well that's interesting, let me just write that. If water is clear, what did you say then?

Jimmy: If it doesn't have a piece of paper under it *(inaudible)* so the sun shines through it.

Mrs. C.: So the sun shines through it. Is that right?

Jimmy: Yes, if water is clear *(making sure the scientific sense of his answer was maintained).*

(Lesson 15, class discussion)

Jimmy's contribution was insightful. He distinguished in a few words, several possibilities that might explain the absence of a shadow when light falls on water. In the process he made it clear that he understood that for shadow formation, light needed to fall on an opaque object and that

unless a screen is present, the shadow cannot be detected. Furthermore, he revealed his capability for reflection on ideas presented by others in class discussion, and his appropriation of those ideas, even though up until now, he had been a silent participant. So, for some children, more questions and suggestions for ways of finding answers continued to be raised in an ever-deepening inquiry into shadow formation.

John reflects in private

Other children, like John, also reflected upon their own experimentation and on this class discussion. John recorded the following comment on one of my tape recorders that I had given out to some class members so that they might ask others about their experiments. I asked children to make certain that interviewers and interviewees identified themselves, as I needed to know who was speaking. In the extract below, John followed this instruction literally, interviewing himself about his views on the class discussion about reflection from water.

> This is John speaking to John. Well, um, well um, we found out that light can reflect off water, and some said: No it can't. And the other person said: Why? um, the other, We said: Why can't it reflect off um, why can't light reflect off water? And um it was because um, they think because um, the light goes right through. But when it's night time, it might not be the same. You go and you get, you get a plastic ball, ball and you um and you go at night time to the beach. And when the moon shines down at the water, you see, if you look under it, and if you don't fall in, you look under it, then um, then um, then you see if there's light. Thank you for listening.
> (John, reflection on children's experiments and on Lesson 15 class discussion)

In the first part, John spoke about results of the experiment he and his friend performed outside, where they found that light reflected from water. Then he outlined the problems raised in class discussion, where some children maintained that light would not reflect from water as it would travel through the water. At the end, in a clever thought experiment, he raised the possibility that the situation might be different at night (or more easily observed at night) and proceeded to outline an experiment that could prove his theory.

It is clear that John believes that moonlight shining down on the water would be reflected upwards from the water, hitting the bottom of a plastic ball held over the water. For a physicist, the theories of reflection and light travelling are important and the physicist seeks to make general laws that hold in many situations. For John, it is the whole analytic unit that makes sense, and this includes the experimenter needing to take care not to fall in the water. Six-year-old John's reflection on his learning exemplifies the power for children of emergent contexts that can arise from learning and teaching models that stimulate reflection and urge creative thought.

Sarah develops her thinking through reflection during the Unit

Sarah was a willing contributor to class discussion and listened intently to the contributions of others. In Lesson 10, she wrote in her Light Log: "I want to know how shadows are formd" *(sic)*.

On one of the many occasions I spoke to Sarah, (Lesson 12), she was drawing a picture of herself, her shadow and the sun in her Light Log after the class activity of tracing around shadows outside. Her drawing seemed to indicate that she did not understand the orientation of the sun, herself and the shadow and I asked if her drawing was meant to show these positions accurately. She considered the drawing for a few minutes, then coloured over her yellow sun to make it part of the blue sky and pasted in a "pop-up" sun, a drawing of the sun that rose above the page when she opened the Light Log. She solved the problem of representing the orientation in a novel and accurate fashion.

I continued the conversation, asking her whether she had obtained an answer to her question about shadow formation.

Gilda: I noticed one of your questions was 'How are shadows formed?' Do you think you have got that figured out yet?
Sarah: I don't really know.
Gilda: What are you thinking at the moment?
Sarah: Well, I know that if the sun is in front of you or behind of you it is in front. It's the opposite way, but I am not really that sure on how they are formed.
Gilda: Have you heard what some people in the class think?
Sarah: Yes.
Gilda: What have they said?
Sarah: They said the sun's coming down and if there's something in its way, then it blocks it and makes a shadow. If we didn't have a sun then we wouldn't have any light and so if you block the sun out, it forms a shadow.
Gilda: And are you a bit doubtful about that?
Sarah: I don't know how it is formed, there's no wrong and no right.
(Lesson 12, Interview with Sarah)

Inspection of Sarah's answer to the question about how shadows are formed reveals that her answer "I don't really know" is to be taken literally. Although she has heard other children's ideas, either she cannot decide between competing explanations, or none as yet make sense to her. Perhaps she is in the process of reflection on the merits of ideas expressed in class by John and others, and is deliberately refraining from making a decision until she has more evidence. By the time of the final interviews, Sarah was no longer in doubt about the answer to her question. She stated:

> I think I know how it's formed. Like the sun comes down and it shines on you and you're blocking its rays, so it makes a shadow. So it's just like in the night, when the sun goes down, and there's the moon and everything like that and like it's night behind

you because you're blocking the sun and it looks like it's going down. (Sarah, final interview, November, 1993)

Sarah's insight is profound. It appears that she had been able to imagine herself in her own shadow and hence lose sight of the sun "like in the night".

Another conversation that I will now discuss, took place during this same interview and makes it plain that this young child does make conscious decisions to remain open-minded when weighing up alternative explanations for events.

In the second part of the Unit, some class discussions centred on the notion that light travels (Lesson 20). This puzzled children in Class 1/2C, although some children proposed means by which light could move (e.g. carried by wind). After class discussion in Lesson 21, Sarah wrote in her Light Log: "I think the light is too heavy so it falls down on to earth." In her final interview, as we discussed this page of her Light Log, she revealed ways in which she reflects on ideas and on evidence for those ideas.

Sarah: Sometimes when I get some ideas from other people, then I don't and then I really think about it, I think no, because whatever they said, like say they said, it's travelling, then I think, well it couldn't travel, because how would it travel?
Gilda: Yeah.
Sarah: And then I think, no I'll stay with that, for the moment, until I get a better idea.
Gilda: And is this still your best idea for the moment?
Sarah: Yep.
(Sarah, final interview)

So Sarah is a consciously reflective thinker, prepared to be patient until she feels that her understanding would enable her to answer penetrating questions about someone's explanation for an event. Knowing this, my interpretation of her earlier statement that "there is no wrong and no right", is that it carries an unstated proviso, that there is no wrong and no right *yet*, until evidence can be provided to support some ideas more than others. The extended time of this Unit has allowed Sarah to develop her thinking at her pace and also, to reflect on her thinking through participating in a sociodramatic play in her final interview (Segal & Cosgrove, 1994). Contexts that emerged during this unit have nourished reflection about light and shadows for Sarah and she has appropriated a scientifically accurate explanation of shadow formation.

DISCUSSION OF FINDINGS

This section extends analysis of emergent contexts that arose in this study in two ways: first by searching for further understanding of types mediational means not so far discussed that assisted different children's appropriation of ideas in the light and shadows context; second by revisiting interconnected sociocultural factors that are inextricably interlinked as mediational means for

appropriation of learning about light and shadow formation in this study - the role of the teacher, the value placed on participation in learning by children and their parents, the On-Going Thinking Model, the part the Light Logs played in children's reflection on learning.

Emergent contexts and mediational means

Generating, testing and reflecting upon ideas

The second part of the Unit continued with activities designed to encourage children to think about how shadows are formed. In Lesson 18, Mrs. C. supplied flashlights and little toy figures of people that were about the same length as the diameter of the glass at the end of the flashlight. I often had a queue of children waiting to tell me what they had observed during their investigations. In that lesson as in others, children needed to weigh up the alternatives of waiting for me to finish talking to others or continuing to investigate shadows. Joel (Year 1) was keen to talk and had waited patiently until I had spoken to others in front of him.

Joel: I put that around and I turned the light on. And I put this over it. It looks like a shadow of the man. *(He had rested the little figure on the glass of the flashlight, then wrapped some paper over the top.)*

Gilda: Why do you think that happens, Joel?

He looked puzzled.

Gilda: Joel? Now isn't that interesting. You might like to go and work out why that shadow of the man is there.

Joel stayed where he was, with other children jostling behind him, waiting for their turn to talk to me.

Gilda: Joel, have you got an idea about why that shadow might be there? No? Well keep on thinking about that. That's a good one.
(Lesson 16, conversation with Joel)

About 5 to 10 minutes later, Joel came rushing back, while another child, Sam, was talking to me.

Joel: I've just thought why!

Gilda: Oh, have you? But can you be patient because it's not really fair to Sam. I'd love to hear why. Keep it in your head. (Lesson 16, conversation with Joel)

My conversations with Sam and other children waiting took about 10 minutes, but Joel waited to speak to me, not even moving when the bell for lunch rang.

Gilda: And what have you worked out Joel?

Joel: See how it makes the light, well, you put that on, *(i.e. the little figure of a man)* it blocks the light coming onto that *(the paper)* and it *(the whole arrangement)* makes its shadow. (Lesson 16, conversation with Joel)

Joel's explanation of shadow formation was accurate. He pointed to the flashlight as the source of light ("See how that makes the light"); he put his object between the light and his paper screen that

he held over the flashlight glass, and explained the shadow formation as the light being blocked by his little figure.

Joel's pleasure in his explanation recalls Duckworth's (1987) essay that similarly records children's intellectual excitement when they raise the right question for themselves and answer it. The context that emerged for Joel provided mediational means for him to take several initiatives without instruction and without setting a time limit before being told what to do: He devised his own experiment (or decided to copy the experimental arrangement from another child); he decided to tell me about his observation; he puzzled about a possible explanation of shadow formation and acted upon my suggestion to think about it; he decided to tell me about his idea. Later Joel made more decisions: He reported his finding to the class and drew it in his Light Log. Indeed Joel was prepared and expected by Mrs. C. to take responsibility for his learning, but the explanation for his actions lies within the whole analytic unit, the emergent context constituted by the sociocultural relational factors of learning model, teacher, other children, participant-observer-researcher, classroom culture, materials available for experimentation.

Several children came to show me similar experiments and some children also explained that the figure blocked the light, thus making the shadow. The convenient size of the little figure, just fitting on top of the flashlight and children's initiative in obtaining construction paper from elsewhere in the room to act as a screen, made this particular mediational means rather useful in helping them move towards a scientific idea of shadow formation.

Children did not protest in Class 1/2C when others carried out the same experiments as themselves. I did not detect any of the rancour that accompanied copying in a study that I carried out earlier over a much shorter time period (Segal, 1994). Thus the freedom to copy experimental ideas can be added to mediational means in Class 1/2C by which some children moved towards a scientific understanding of shadow formation.

Seeking alternatives to contributing to class discussion

A few children did not contribute to these class discussions. Occasionally, Mrs. C. included such children in oral discussion, by asking them a very simple, open question, but she more often spoke to them privately, encouraging them separately. Deborah (Year 1) was one such child. She and her friend chatted readily and cheerfully to me in interviews; both girls spoke very softly. Deborah wrote and drew extensively in her Light Log, covering practically every page with written and illustrated reporting on her ideas, feelings and on her own experimentation. For example she wrote in the second part of the Unit:

> When you put the light high, the shadow is big, and when you put it down it is small (Deborah, Lesson 19, Light Log).

At the end of the Unit, she was fascinated with her own question: Does a shadow have a shadow? recorded this in her Light Log, and discussed it with me during our final interview.

I gained further insight into Deborah's thinking and into how her personality inhibited her from joining in class discussion during this final interview. Deborah told me that she had ideas and wanted the class to know about them but that she was shy so she whispered her ideas to her friend, who then told the class. Mediational means for Deborah to develop her ideas and reflect on them included her Light Log, her friend, her teacher who did not ignore her. The Phases of the On-Going-Thinking Model were also mediational means whereby she could participate vicariously in class discussion with the help of her friend, and directly in pairs discussion and in generating and testing ideas in informal inquiry.

Asking questions during the Unit as a reflexive process leading to further questions after reflection on the Unit

Encouraging children to ask questions is central to an interactive teaching approach (Biddulph & Osborne, 1984), an approach that Mrs. C. herself appropriated through her participation in the Whole School Professional Development Program in Science and Technology. During the Unit, Mrs. C. encouraged children to state and investigate their own questions, but her approach was low key. Very few children actually phrased their own investigable questions; they either used those stated by a few children, or engaged in informal inquiry, as did children in an earlier study (Segal, 1994) However, two months after the Unit ended, some children like Deborah, who did not reveal her questions to the class while the Unit was in progress, drew them to my attention during final interviews, without my asking about them. Others, like Laura (Year 1) volunteered to write down for me another question that had occurred to her, again without my asking. She had to go back to class after our interview, but true to her word, sent me her question on a card, "Does the sun have a shadow?"

Two other children opened their final interview conversation with me by raising the matter of questions. Stephie announced that she had a question: "What is light?" Sarah added that she also had a question: "What is the sun made of? Stephie, although she was an advanced reader, had shown a lack of interest in formulating her own questions during the Light Unit and at times, had indicated a lack of confidence in her ability to think of ideas for experiments or explanations for observations of others. Stephie's announcing that she had a question must be regarded as a significant indicator of her appropriation of one facet of science, the facet that actively seeks to know by asking questions.

Thus these children's questions two months after the Unit reveal their reflection on the substance and spirit of the inquiry processes of the Unit, that is, they had appropriated a view of science as science-in-the-making (after Latour, 1987) that included them and their questions. Hence in

retrospect, encouraging children to ask questions during a science unit, can be regarded as mediational means for reflection on seminal aspects of the unit after its completion.

In summary, this section has described contexts that are emergent, constituted through interactions between teacher, children, researcher, the pre-planned Light Unit activities and the On-Going-Thinking Model. Analysis of emergent contexts has shown that they contain the mediational means through which children choose to appropriate science by developing their ideas about shadow formation. Class discussion, some of which developed into transformational interactions, children's generation and testing questions and ideas in informal inquiry and children's reflection-in-action and on their learning have been shown to be particularly salient for such development.

Interconnected Sociocultural Factors and Mediational Means

The role of Mrs. C in children's appropriation of scientific understanding of light and shadows.

The role of Mrs. C. was crucial. Mrs. C.'s educational values and sophistication, discernible prior to the Light Unit, permeated the contexts that arose in this study through relationships she formed with the learning model, with the children and their parents, with the school culture and with me. Through these relationships, children were assisted to articulate their current understanding and further develop their views of the nature of light and of shadow formation.

Values of children and parents

Individual children in this study cannot be separated from their middle class home backgrounds where parents take an interest in their children's education and encourage children to tell them about their school experiences; Australian middle class parents value confident and articulate children. Nor can the advancement of children's thinking be separated from the classroom culture that values cooperation, respect for others and independent thinkers and workers. Children in Class 1/2C were deeply involved in their learning and chose to be successful in terms that were valued by Mrs. C., their parents and themselves. Thus advancement of children's thinking can be attributed to child, teacher and parental characteristics grounded in their culture and values, an aspect of the study's sociocultural context.

The On-Going Thinking Model

The On-Going-Thinking Model facilitated these outcomes over the extended time period of the study. Mrs. C.'s interactions with the children through her implementation of the On-Going-Thinking Model and her allowing them to make genuinely important decisions about their learning, can be plausibly put forward as mediational means for these young children's appropriation of science as a cognitive, social and emotional activity of personal value.

Reflection on learning: The role of the Light Logs

Light Logs provided leisurely opportunities for children to record their learning and reflect upon it at levels that suited them. Those who were just learning to write, included a few words and drawings; some voluntarily took their Light Logs home to complete colouring of drawings and added other adornments. Children treated the Light Log as their personal record. In final interviews, most children were very happy to choose their favourite page to read to me and inquired whether they could take their Light Log home with them. The many assumptions on which use of the Light Log was based, that there were advantages for learners, teachers and researcher were well founded.

In the final section of this paper, I consider implications of my findings and their analysis.

IMPLICATIONS

There are two implications from the deep, generative and autonomous learning that was characteristic of many young children in this study.

1. Learning of so-called abstract concepts of physical science can deeply interest young children and hence their early introduction into elementary school, in a prolonged and non-threatening manner is indicated.
2. Teachers need professional development to function well in the role of learning guide for science education of young children.

First Implication

Science ought to be started early in primary school to allow time for extended discussion of ideas, as in this study. An early start to children's science education has additional advantages that it might foster lasting positive attitudes to science and help challenge and counteract prevailing social and cultural attitudes that associate science (especially physical science) with masculinity, as I have argued elsewhere (Segal, 1995).

Second Implication

Children's appropriation of science in Class 1/2C cannot be considered in isolation from the role of Mrs. C. Mrs. C. appropriated the discipline content of the learning model context and the style of learning and teaching presented during two extended school professional development programs in science education; her expertise and confidence in her own practice was well established at the time of this study and resonated with the underlying developmental philosophy of the programs in which she participated. Therefore, an implication of this study, and from the research of near

colleagues (e.g. Schaverien, 1994) is that further research into the nature of careful and extended teacher preparation is needed to understand conditions that assist teachers to appropriate and implement the perspective on science education exemplified by this study.

ACKNOWLEDGMENTS

I thank the Principal and three teachers at the elementary school for kindly cooperating with me in this research project and in particular, I thank Mrs. C. and the children of Class 1/2C for the privilege of working closely with them - it was a truly delightful experience. I am deeply grateful to Mark Cosgrove for his guidance throughout my research. His scholarship and intellectual capacity for generating new ideas is inspiring.

Note: Throughout this paper, I have substituted the North American words *flashlight* and *Elementary School* for the Australian terms *torch* and *Primary School.*

REFERENCES

Alexander, P. A., Kulikowich, J. M., & Schulze, S. K. (1994). How subject-matter knowledge affects recall and interest. *American Educational Research Journal, 31*(2), 313-337.

Arendt, H. (1971). *Thinking*. (Vol. 1). New York: Harcourt, Brace, Jovanovich.

Bateson, G. (1972). *Steps to an ecology of mind: A revolutionary approach to man's understanding of himself*. New York: Ballantine.

Berk, L. E. (1994). Why children talk to themselves. *Scientific American*(November), 78-83.

Bershon, B. L. (1992). Cooperative problem solving: A link to inner speech. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interaction in cooperative groups: The theoretical anatomy of group learning*, (pp. 36-48). Cambridge: Cambridge University Press.

Biddulph, F., & Osborne, R. (Eds.). (1984). *Making sense of our world: An interactive teaching approach*. Hamilton, N.Z.: S.E.R.U. University of Waikato-Hamilton Teachers College.

Bruner, J. S. (1962). Introduction. In L. S. Vygotsky (Ed.), *Thought and Language*, (pp. v-x). Cambridge, MA: The M.I.T. Press.

Bruner, J. S. (1977). Preface, 1977. In J. S. Bruner (Ed.), *The process of education*, . Cambridge, MA: Harvard University Press.

Cazden, C. B. (1988). *Classroom discourse*. Portsmouth, NH: Heinemann.

Cole, M. (1985). The zone of proximal development: Where culture and cognition create each other. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives*, (pp. 146-161). New York: Cambridge University Press.

Davies, B. (1993). *Shards of glass*. Sydney: Allen & Unwin.

Delamont, S. (1992). *Fieldwork in educational settings: Methods, pitfalls and perspectives*. London: Falmer Press.

Edelman, G. M. (1993). Neural Darwinism: Selection and reentrant signaling in higher brain function. *Neuron, 10*(2), 115-125.

Edwards, D., & Mercer, N. (1987). *Common knowledge: The development of understanding in the classroom*. London: Routledge.

Engeström, Y. (1986). The zone of proximal development as the basic category in educational psychology. *Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 8*, 23-42.

Entwistle, N. (1988). *Styles of learning and teaching*. London: David Fulton.

Foucault, M. (1977). *The archeology of knowledge*. London: Tavistock.

Gee, J. P. (1990). *Social linguistics and literacies: Ideology in discourses*. London: Falmer Press.

Gee, J. P. (1994, April). "Science talk:" How do you start to do what you don't know how to do?, *Annual Meeting of American Educational Research Association*, . New Orleans.

Geertz, C. (1973). *Interpretation of cultures*. New York: Basic Books.
Harel, I., & Papert, S. (1990). Software design as a learning environment. *Interactive Learning Environments Journal, 1*(1), 1-32.
Kenway, J., Willis, S., Blackmore, J., & Rennie, L. (1994). Making 'hope practical' rather than 'despair convincing': feminist post-structuralism, gender reform and educational change. *British Journal of Sociology of Education, 15*(2), 187-210.
Latour, B. (1987). *Science in action*. Cambridge: Harvard University Press.
McCrone, J. (1993). *The myth of irrationality*. London: Macmillan.
Millson, P., & Sington, D. (Eds.). (1994). *The man who made up his mind*. London: British Broadcasting Corporation.
Newman, D. (1990). Cognitive change by appropriation. In S. P. Robertson, W. Zachary, & J. B. Black (Eds.), *Cognition, computing and cooperation*, (pp. 84-94). Norwood, NJ: Ablex.
Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: Working for cognitive change in school*. Cambridge: Cambridge University Press.
Osborne, J., Black, P., Smith, M., & Meadows, J. (1990). *Light-Science process and concept exploration project report*. Liverpool: Liverpool University Press.
Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*, 167-199.
Posner, G. J., & Gertzog, W. A. (1982). The clinical interview and the measurement of conceptual change. *Science Education, 66*(2), 195-209.
Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.
Schaverien, L. (1994). *Learning and teaching technology-and-science: A primary school perspective*. Unpublished Ph.D. dissertation, University of Technology, Sydney, Sydney.
Seddon, T. (1991). Rethinking teachers and teacher education in science. *Studies in Science Education, 19*, 95-117.
Segal, G. (1994, March,). *"The shadow is there and you just can't see it." A learning environment for young children to investigate shadows*. Paper presented at the National Association for Research in Science Teaching (NARST), Anaheim, CA. ERIC Document No. 368 575.
Segal, G. (1995). *Revaluing primary science education: A developmental, gender inclusive perspective*. Unpublished Doctor of Philosophy, University of Technology, Sydney, Sydney.
Segal, G., & Cosgrove, M. (1994). "I want to find out how the sun works!" Children's sociodramatic play and its potential role in early learning of physical science. *Research in Science Education, 24*, 304-312.
Segal, G., & Cosgrove, M. (1995, April). Promoting loud thinking about light in elementary school science, *Annual Meeting of National Association for Research in Science Teaching (NARST)*, San Francisco. ERIC Document No. ED 391 652.
Smith, M. L. (1987). Publishing qualitative research. *American Educational Research Journal, 24*(2), 173-183.
Spelke, E. (1991). Physical knowledge in infancy: Reflections on Piaget's theory. In S. Carey & R. Gelman (Eds.), *The epigenesis of mind: Essays on biology and cognition*, (pp. 133-169). Hillsdale, NJ: Lawrence Erlbaum.
Strike, K. A., & Posner, G. J. (1985). A conceptual change view of learning and understanding. In L. H. T. West & A. L. Pines (Eds.), *Cognitive structure and conceptual change*, (pp. 211-231). New York: Academic.
Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to development of cognition and action*. Cambridge, MA: MIT Press/Bradford Books.
Thelen, E., & Ulrich, B. D. (1991). Hidden skills: A dynamic systems analysis of treadmill stepping during the first year. *Monograph of the Society for Research in Child Development, 56*(1, Serial No. 223).
Tobias, S. (1994). Interest, prior knowledge and learning. *Review of Educational Research, 64*(1), 37-54.
Trevarthen, C. (1992). An infant's motives for speaking and thinking in the culture. In A. H. Wold (Ed.), *The dialogical alternative*, . London: Scandinavian University Press.
Vygotsky, L. S. (1962). *Thought and language* (Hanfmann E. Vakar, G., Trans.). Massachusetts: M.I.T. Press.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner and E. Souberman, Trans.). Cambridge: Harvard University Press.

Wertsch, J. (1991). *Voices of the mind. A sociocultural approach to mediated action.* Cambridge, MA: Harvard University Press.

Wertsch, J. V., Tulviste, P., & Hagstrom, F. (1993). A sociocultural approach to agency. In N. Minick, C. A. Stone, & E. A. Forman (Eds.), *Contexts for learning. Sociocultural dynamics in children's development,* (pp. 336-356). New York: Oxford University Press.

Wilensky, U. (1991). Abstract meditations on the concrete and concrete implications for mathematics education. In I. Harel & S. Papert (Eds.), *Constructionism,* (pp. 193-203). Norwood, NJ: Ablex.

Wittrock, M. C. (1994). Generative science teaching. In P. J. Fensham, R. F. Gunstone, & R. T. White (Eds.), *The content of science: A constructivist approach to its teaching and learning,* (pp. 29-38). London: Falmer Press.

Wood, D. (1988). *How children think and learn.* Oxford: Basil Blackwell.